An Adaptive management process for forest soil conservation[1]

Michael P. Curran[a2], Douglas G. Maynard[b], Ronald L. Heninger[c], Thomas A. Terry[d], Steven W. Howes[e], Douglas M. Stone[f], Thomas Niemann[g], Richard E. Miller[h], and Robert F. Powers[i]

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[2] Corresponding author, [a]B.C. Ministry of Forests, Forest Science Program, 1907 Ridgewood Rd., Nelson B.C., Canada, V1L 6K1. (also, Adjunct Professor, Agroecology, University of B.C.). Phone: 250-825-1100. E-mail: mike.curran@gems5.gov.bc.ca; website: http://www.gov.bc.ca/for/

[b]Natural Resources Canada, Canadian Forest Service, 506 West Burnside, Victoria, B.C., Canada, V8Z 1M5. Phone: 250-363-0600. E-mail: dmaynard@pfc.forestry.ca website: http://www.nrcan.gc.ca/cfs-scf/

[c]Weyerhaeuser Company, P.O. Box 275, Springfield, OR, USA. 97478-5781; Phone: 541-741-5368 E-mail: ron.heninger@weyerhaeuser.com

[d]Weyerhaeuser Company, Box 420, Centralia, WA, USA. 98531 Phone: 360-330-1746 E-mail: tom.terry@weyerheauser.com

[e]USDA Forest Service - Pacific Northwest Region P.O. Box 3623, Portland, OR 97208-3623 Phone: 503-808-2937 E-mail: showes@fs.fed.uswebsite: http: www.fs.fed.us

[f]USDA Forest Service, North Central Research Station, Forestry Sciences Laboratory, 1831 Hwy 169 E, Grand Rapids, MN 55744 Phone: 218-326-7117 E-mail: dstone01@fs.fed.uswebsite: http://www.fs.fed.us

[g]B.C. Ministry of Forests, Forest Practices Branch, P.O. Box 9513, Stn.Prov.Govt., Victoria, B.C., Canada. V8W 9C2 Phone: 250-881-8883 E-mail: Tom.Niemann@gems6.gov.bc.ca Website: http://www.for.gov.bc.ca/hfp/hfp.htm

[h]Emeritus Scientist, Pacific Northwest Research Station, Forestry Sciences Laboratory, 3625, 93rd Avenue S.W., Olympia, WA 98512-9193 Phone: 360-753-7684 E-mail: millersoils@aol.com Website: http://www.fs.fed.us

[i]USDA Forest Service, Pacific Southwest Research Station, 2400 Washington Ave., Redding, CA. 96001 Phone: 530-242-2455. E-mail: rpowers@c-zone.net Website://www.fs.fed.us

Abstract

Soil disturbance guidelines should be based on comparable disturbance categories adapted to specific local soil conditions, validated by monitoring and research. Guidelines, standards, and practices should be continually improved based on an adaptive management process, which is presented in this paper. Core components of this process include: reliable monitoring protocols for measuring and comparably describing soil disturbance for operations, sustainability and certification protocols; effective methods to predict the vulnerability of specific soils to disturbance and related mitigative measures; and, quantitative research to build a database that documents the practical consequences of soil disturbance for tree growth and soil functions.

Keywords: Soil disturbance; Soil compaction; Rutting; Monitoring (implementation, effectiveness, and validation); Criteria and indicators; Montreal Process

Introduction

A number of models exist for the development and continual improvement of guidelines and standards for sustainable forest management (e.g., ISO 14001 (ISO 2001). However, there is no consensus on components required in such models to ensure conservation and possible enhancement of soil productivity. This paper presents an adaptive management framework for soil disturbance that supports internal operations and policy as well as external reporting for due-diligence in forest soil management. To support this framework, common language and key components should be defined and agreed upon (Curran et al. 200x). These components include clear definitions of the various types of monitoring, which are critical to the adaptive management process.

It would be mutually beneficial for agencies and companies to cooperate and develop the key components of reliable soil management procedures. This would:

- ensure continuous evolution of Best Management Practices (BMPs),
- enable coordinated development and implementation of training materials and new tools,
- facilitate reporting for sustainability protocols and meeting objectives of third-party certification, and
- enhance the exchange and application of research results from various sources.

Long-term research in representative ecosystems is essential for understanding and managing the effects of forest practices on long-term soil productivity. Regional databases need to be developed

to quantify the consequences of various practices and treatments on tree growth, soil-plant processes, and other forest resources like water quality.

Internal operations and policy within a given jurisdiction

The adaptive management process that has evolved based on the British Columbia (B.C.) Forest Practices Code and related soil disturbance guidelines (B.C. Ministries 1995a), and now the Forest and Range Practices Act (FRPA), demonstrates useful adaptive management components (Figure 1). These are not unique to any one organization or jurisdiction and other recent examples of similar frameworks include the presentation by Terry et al.[3] and the World Forestry Congress handout by Jette[4]. We suggest that scientists can and should contribute to all components of the adaptive management cycle, by developing procedures, providing strategic data from research, and consulting on guidelines, operations and BMPs. Participating in these activities provides opportunities for scientists to better understand the practical issues of sustainability. Due to limited resources and a large land base, B.C. Ministry of Forests (BCMoF) scientists are responsible for both research and operational support, ensuring this integration. To have an effective adaptive management process for soil conservation, each jurisdiction needs to address three objectives: (1) more uniform terms for describing soil disturbance; (2) cost-effective techniques for monitoring or assessing soil disturbance; and (3) reliable, site-specific methods to rate soils for risk of detrimental soil disturbance (Curran et al. 200x). These are briefly discussed below:

[3] Terry, T.A., R.L. Heninger, and R.G. Campbell. Sustainable site productivity: A forest industry perspective. Paper presented at LTSP2000 conference, Alexandria, Louisiana.

[4] Jette, J-P. Protecting forest soils through an adaptive management approach. Research note (describing Quebec soil disturbance standards and monitoring results). Tabled at the XII World Forestry Congress – Quebec, Canada 2003.

More uniform categories of soil disturbance

All jurisdictions responsible for regulating forest soil disturbance require clear definitions of disturbance caused by permanent access such as haul roads, and in-block disturbance caused by forest practices such as harvesting. Currently, many classification systems exist for characterizing soil disturbance related to rutting, soil compaction, displacement, and mixing. Consequently, it is difficult to compare results without first correlating the different systems and developing a common language for such comparisons. The objective is to have visually identifiable, unambiguous, commonly used categories of disturbance that are:

- inclusive of the range of disturbance likely to occur,
- visually discernible and readily recognized by equipment operators or lay people,
- classed as detrimental (for tree growth or hydrology), or as ameliorated,
- site-specific, and
- consistent with on-going validation monitoring (research) that tests the assumptions of "detrimental", or "ameliorated" to site productivity or hydrology.

Curran et al. (200x) discuss examples of visual disturbance criteria developed by BCMoF, Weyerhaeuser, and the United States Department of Agriculture, Forest Service (USFS).

Cost-effective monitoring to facilitate reliable comparisons

The USFS recognizes three types of soil quality monitoring (Avers 1990; USFS 1991):

- **Implementation monitoring** tests if the prescribed soil management practices have been implemented as designed or authorized (e.g., is the disturbance level within the acceptable limits?). This is also referred to as compliance monitoring which is an important requirement for third-party certification.
- **Effectiveness monitoring** tests if the prescribed soil management practices were effective in meeting management objectives (e.g., do authorized harvesting systems efficiently meet the disturbance target? Are sensitive soils identified and treated adequately?).
- **Validation monitoring** tests the assumptions of the monitoring standards and guidelines to ensure they are appropriate for maintaining soil productivity (e.g., do specific disturbance types actually result in a significant or measurable loss in productivity?).

In B.C., implementation monitoring is carried out by compliance and enforcement staff at the Forest District level, effectiveness evaluations are now required under FRPA and are carried out at the District, Region, and Provincial levels depending on the level of detail, and validation monitoring is carried out by the Ministry Research (Forest Sciences) Program. In the USFS, implementation monitoring is usually accomplished by planners, timber sale, and contract implementation staff. Effectiveness and validation monitoring are the responsibility of soil scientists. Validation monitoring may require involvement by, or coordination with, research scientists.

The purpose of implementation (compliance) monitoring of soil disturbance is to estimate the percentage of a total area in specified disturbance categories. This estimate is then compared with allowable limits. This presumes that meeting standards ensures no subsequent effects on soil

productivity. This assumption needs to be tested by effectiveness monitoring and research on actual effects on tree growth and hydrology. One example of soil compaction and organic-removal research is the North American Long-Term Soil Productivity network (Powers et al. 1998).

As outlined in Table 1, methods and intensity vary by types of monitoring and must strike a balance between affordability and utility (credibility). Visual assessment of soil disturbance is qualitative by nature, relatively inexpensive and can provide a reasonably efficient measure of soil disturbance, making them preferable for compliance monitoring. More quantitative measures of soil disturbance, such as soil physical properties, are more expensive. These are appropriate when testing assumptions as part of validation monitoring and long-term research. Direct evidence provided by measuring tree growth or hydrologic functions is the preferable outcome. Where appropriate, including non-harvested controls (baseline monitoring) may help detect trends due to processes like climate change.

Thus, implementation, effectiveness, and validation monitoring are three categories of monitoring that are all needed to improve this adaptive management process (Avers 1990). Moreover, we advise that statistical advice and support is needed for all three types of monitoring. Effectiveness monitoring and validation monitoring reach their full potential when used in combination (Lee and Bradshaw 1998). For example, knowing that trees may not be growing well in an area (effectiveness monitoring) is of little value without some knowledge that the observed effect is due to management activities (validation monitoring). Budgeting of resources for monitoring activities is typically based on risk management that considers severity and extent of resource management concerns.

Risk or hazard ratings for site-specific application of soil disturbance guidelines

Risk ratings are interpretations (predictions) of the vulnerability of a given soil to a specified process (e.g., compaction) and assist in planning and implementation of forest operations. Five soil-disturbance hazards were originally defined for forest practices in B.C. (B.C. Ministries 1995b): soil compaction, displacement, forest floor displacement, surface soil erosion, and mass wasting. These are often relevant to other jurisdictions and address the same disturbance processes recognized by the USFS nation-wide (Powers et al. 1998). Risk-rating systems for these processes focus on soil physical properties (e.g., texture) and may be combined with site factors related to topography and drainage. For example, the BCMoF compaction-hazard key is based mainly on soil texture and coarse fragment content.

We need to develop and test rating systems to ensure they reflect the site-specific differences that are observed during operations and research. For example, on sandy soils in southern B.C. we have found that percent clay appears to influence disturbance effects on tree growth. These sites would be rated the same under current guidelines, but because growth results typically differ with the clay content (Figure 2), such research will lead to adaptive changes in rating systems and guidelines. A remaining challenge is to justify localized rating systems, while still ensuring comparability across jurisdictions to enable sharing operational and research knowledge.

Data for hazard ratings may be based on detailed soil mapping at a 1:24,000 or larger scale. This is the level at which most direct risk-rating methods have been developed in the US Pacific

Northwest. On-site inspection is still needed to confirm accuracy of the mapping and the actual soil series to be rated. In the absence of detailed soil mapping, each area proposed for harvest requires its own soil assessment as part of harvest planning; this is the procedure used in B.C. (Curran et al., 2000).

External reporting on research, guidelines, and protocols

Outputs from internal adaptive management within a jurisdiction can and should facilitate the development of effective approaches for using operational monitoring to meet various external objectives, including requirements of third-party certification and international protocols like the Montreal Process; and objective comparisons of current soil-disturbance guidelines.

Using results of operational monitoring to meet various protocols

The Montreal Process (MP) identified seven criteria and 67 indicators to characterize conservation and sustainable management of temperate and boreal forests. Criterion 4 encompassed the conservation and management of soil and water resources. Of its eight indicators, five are related to soil and three are related to water. In addition, Criterion 3 (Maintenance of Forest Ecosystem Health and Vitality) and Criterion 5 (Maintenance of Forest Contribution to Global Carbon Cycles) also relate to soils (Ramakrishna and Davidson, 1998).

In the First Approximation Report (MP Working Group, 1997), the soil and water conservation criterion was the most difficult to report. Gaps in knowledge, monitoring, and data were identified

at about 60% for the indicators of soil and water resources criterion. Further problems with indicators included a lack of appropriate measures, issues of scale, and monitoring approaches (MP Working Group, 1997). These problems are understandable because of the need for a common language for soil disturbance, but also because all but one of the soil indicators are: "those which may require the gathering of new or additional data and/or a new program of systematic sampling, or basic research" (b-type indicators).

Agencies such as the Canadian Council of Forest Ministers (CCFM 2003) have developed national level indicators that use the status of local standards as proxies for the more detailed MP b-type indicators. The underlying assumption is that ongoing adaptive management and research will test these proxies against the MP indicators. The rationale is that MP indicators are too onerous to track everywhere, and local-level standards should already be addressing these sustainability issues. Well designed and carefully executed adaptive management process will help identify soil properties that are critical to measure and report (regionally, nationally and internationally). This mirrors the process used by the USFS since 1987. Each region of the U.S. has been developing and modifying soil quality threshold standards aimed at detecting a 15% decline in a site's potential capacity for growing vegetation (Powers et al. 1998). Because these standards vary by region, and they are in continual upgrade, they are by definition adaptive. A similar process supports the B.C. standards.

Comparable soil-disturbance guidelines across jurisdictions

Soils are distributed on both sides of international borders and other ownership and administrative boundaries. For example, B.C. borders three U.S. Forest Service Regions, four U.S. states, other U.S. jurisdictions (e.g., U.S. Bureau of Land Management), private forest companies, and three other Canadian provinces and territories. Thus, fundamental compatibility of guidelines across jurisdictional boundaries is desirable. We acknowledge that agencies and landowners will view risk differently based on their mandates and management objectives. Individual guidelines will reflect these differences. We assert, however, that similar principles of soil conservation and management should be applied in all jurisdictions.

Some resource management tools also exist across jurisdictional boundaries. For example, soil mapping or ecological unit inventories may support extrapolating monitoring results, adjusting definitions of soil disturbance categories, or adjusting soil-quality standards across jurisdictional boundaries. Technical committees currently operating or proposed for regional, national, and international levels should compare soil management procedures and tools. They should explore opportunities for improving consistency in approaches; this is currently being started at the regional level in the Pacific Northwest under the auspices of the NW Forest Soils Council. At the National level, a Canadian Forest Soil Disturbance Working Group has started some initial activities towards this common goal, under the direction of the first two authors of this paper.

Summary

Soil conservation should be based on an adaptive management process. Necessary components include common soil disturbance categories, reliable protocols for measuring and describing soil disturbance, and effective risk-rating to categorize soil sensitivity or anticipated degree of degradation (e.g., degree of compaction). Moreover, long-term research is needed to quantify the effects of forest management practices on sustainability indicators and their linkages with direct measures of tree growth and soil function.

We suggest that the following summary points are relevant to most sustainable forest resource management issues:

- All components of the adaptive management process outlined in Figure 1 are critical to the overall success of sustainable forest management.
- There needs to be clear distinction amongst the three types of monitoring required for adaptive management. Roles and responsibilities associated with these activities require clarity.
- There needs to be an adequate balance of effort spent on the various types of monitoring.
- There needs to be clear links between monitoring activities, local "state of the resource" reporting, and reporting for third-party certification and protocols like the MP. The proposed use of standards as proxies needs validation.
- Longer-term research is critical: to test assumptions of sustainability guidelines, to demonstrate sustainability, and to adjust guidelines and practices as more data becomes available about specific sites or practices.

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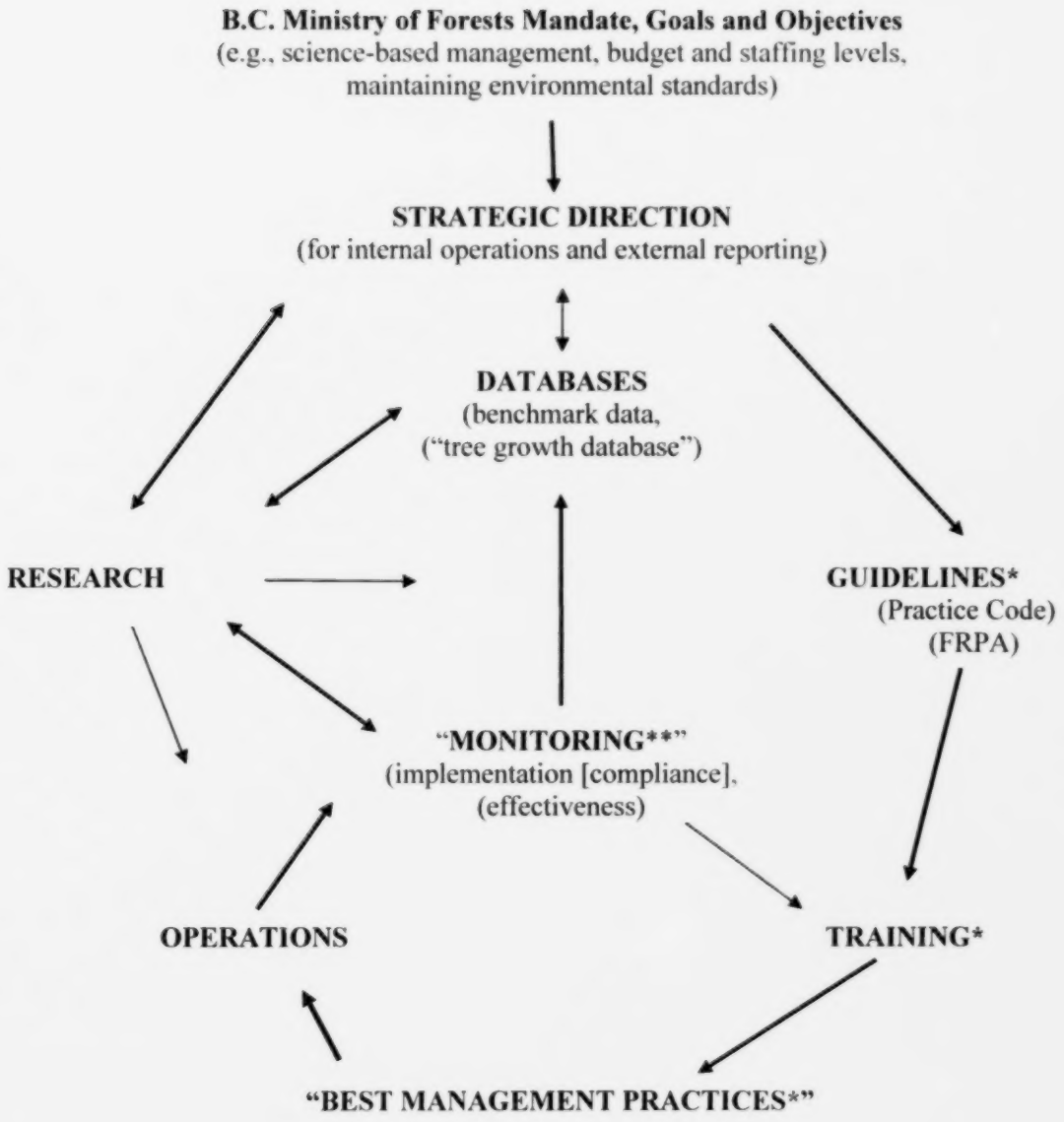
Table 1. General characteristics of monitoring categories applied to soil disturbance.*

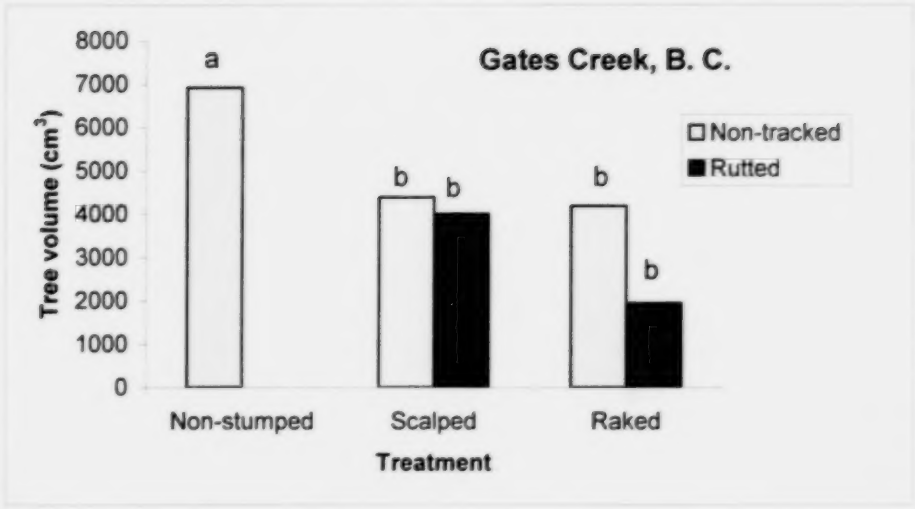
	Type of monitoring		
Item	**Implementation** (compliance)	**Effectiveness**	**Validation**
Duration	Duration of development activity	Short to medium-term	Medium to long-term
Intensity of data collection and analysis	Low to Medium	Medium	High (intensive)
Area sampled	Entire operating area	Representative operating areas	Representative ecosystems
Principal activities and objectives	Compliance and enforcement; Basic data on disturbance levels	Do standards work? Optimum prescription? Data on what does and doesn't work	Controlled experiments; Other trials; Data testing underlying assumptions
Outcomes	Data for penalties and reporting; Priorities for effectiveness and validation monitoring	Modify policy and BMPs; Identify validation monitoring and research needs	Published science; Recommendations for improving policy, guidelines, and practices
Responsibility	Approving agency or landowner (technical staff, third-party auditors)	Staff specialists	Research scientists

*Risk assessment is presumably used to apply the greatest monitoring resources to highest risk, highest priority areas. Conversely, less resources (less frequent, less intensive monitoring) are allocated to the lowest risk areas. Risk elements will vary based on values of concern (e.g., social, environmental, forest productivity).



*denotes link to Research, but only small arrows shown for clarity.
**"Monitoring" refers to implementation, effectiveness, and validation monitoring in association with Research

Figure 1. Adaptive Management ("Reliable Process") Model for Soil Disturbance in B.C.



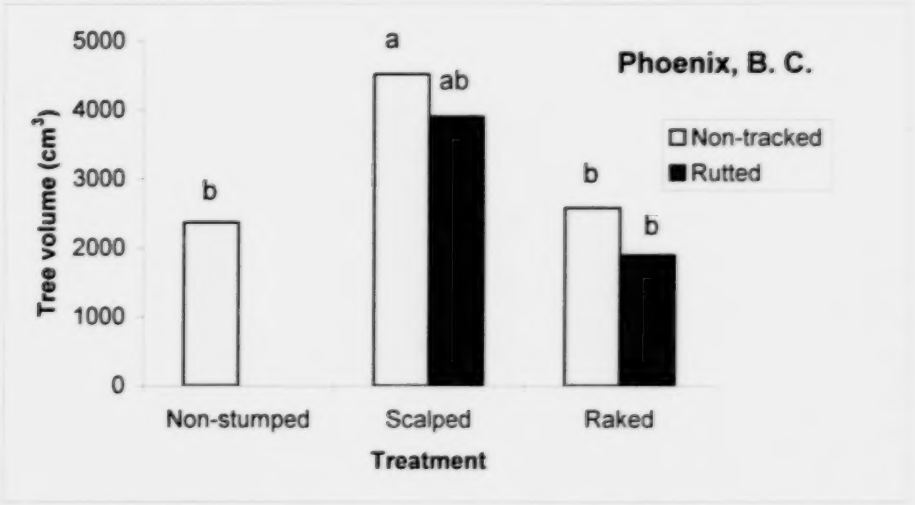


Figure 2. Mean tree volume of Douglas-fir at 15 years on two gravelly sandy loam soils, but differing in clay content (Gates Creek, B.C. 12% clay, slightly plastic to plastic and Phoenix, B.C. 4% clay, non-plastic). Treatment descriptions: Non-stumped (harvested and slash windrowed but stumps not removed); Scalped (harvested, stumps removed and windrowed with slash); Raked (harvested stumps removed and windrowed with slash, cutover raked with a brush blade to bring large roots to the surface). Letters a and b denote significant differences ($p<0.05$) within a site (adapted from Wass and Senyk 1999).